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PLANETARY QUARANTINE

QR 6

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SANDIA LABORATORIES QUARTERLY REPORT - PLANETARY QUARANTINE PROGRAM

PLANETARY QUARANTINE DEPARTMENT 2570

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SANDIA LABORATORIES

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Sandia Laboratories Quarterly Report - Planetary Quarantine Program

Sixth Quarterly Report of Progress

for

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Planetary Quarantine Department
Sandia Laboratory, Albuquerque, New Mexico

September 1967

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The following is a summary of the Planetary Quarantine Department activities being pursued, and the progress made, during the third quarter of calendar year 1967.

1. Program Development and Analysis

   A. Description. It has been assumed that there is a need for a precise way of determining what specific actions are needed in order to achieve planetary quarantine objectives. The determination of these specific actions in a cost-optimal fashion is termed "program development and analysis".

   B. Progress. As reported in the previous quarterly report, a scheme has been developed which lends insight into how one may determine the desired actions on a cost-optimal basis. Several reports on this approach are in preparation, and a detailed description will soon be available in a paper entitled, "A Systems Approach to Contamination Control" to appear in the Proceedings of the NASA/AEC sponsored Symposium on Current and Advanced Concepts in Instrumentation and Automation in Contamination Control, held September 12-14 in Albuquerque. Progress in implementing this scheme is dependent upon progress made in the modeling discussed below.

2. Modeling of Primary Objectives.

   A. Description. The first step in program development and analysis is the relating of the primary objectives of the program to the "significant factors" influencing their attainment.

   B. Progress. A model has been developed and is available in "A Sequential Decision Model of Planetary Quarantine Primary Objectives", Sandia Laboratories Research Report, SC-RR-67-462. A detailed description may be found, also, in the previous quarterly report. A slightly revised model was developed this quarter to incorporate _a posteriori_ probabilities into the model, proper, rather than as an adjunct to it. A paper entitled "A Multistage Decision Model for Mission Non-Contamination Requirements" has been submitted for publication in the open literature. This activity is currently considered completed.

3. Modeling of Secondary Objectives

A. Description. In the theory of Program Development and Analysis described under Activity 1, above, one may derive "secondary objectives" from "primary objectives" when the modeling of the primary objectives is completed. These, in turn, are analyzed, that is, they are related to the "significant factors" influencing their attainment with the aid of models.

B. Progress. In order to be specific in modeling the secondary objectives, it is necessary to be precise about the meaning of the word "contamination". This refers not only to agreement on what materials or life-forms will be considered contaminants, but also to agreement on what contaminants must "do" to constitute "contamination". If it is assumed that terrestrial life forms are to be considered the only contaminants, one must still know what consequences of their presence will be considered "contamination".

Some possible choices for the meaning of the word "contamination" are: viable terrestrial life-forms constitute "contamination" of a planet if they

(i) are present on or in a space vehicle in contact with the planet, or

(ii) are present on the planet's surface, or

(iii) result in "biased experimentation", i.e., yield results that would not have been gotten were they not present, or

(iv) alter the ecology of the planet in any "significant" way.

Roughly speaking, these are listed in decreasing order of implied "stringency".

A model of secondary objectives has been developed under the assumption that "contamination" of a planet results when viable terrestrial life-forms cause biased experimentation on a planet. A preliminary report is being prepared.

4. Modeling Third and Fourth Level Objectives.

A. Description. Continuing the process outlined above in Program Development and Analysis, lower level objectives must be analyzed.

B. Progress. Analysis of third and fourth level objectives has been begun. Some areas have been completely modeled, and work is continuing on the remainder. One particular difficulty relating to the fourth (and, possibly, subsequent) level(s) is a need for a reliable model of microbial deactivation. This is discussed separately below.

5. Microbial Death Models.

A. Description. A reliable model of microbial deactivation is needed for reasons hinted at above and described in more detail both in the preceeding quarterly report and in "A Rational Model for Spacecraft Sterilization Requirements", Sandia Laboratories Research Report, SC-RR-67-256.

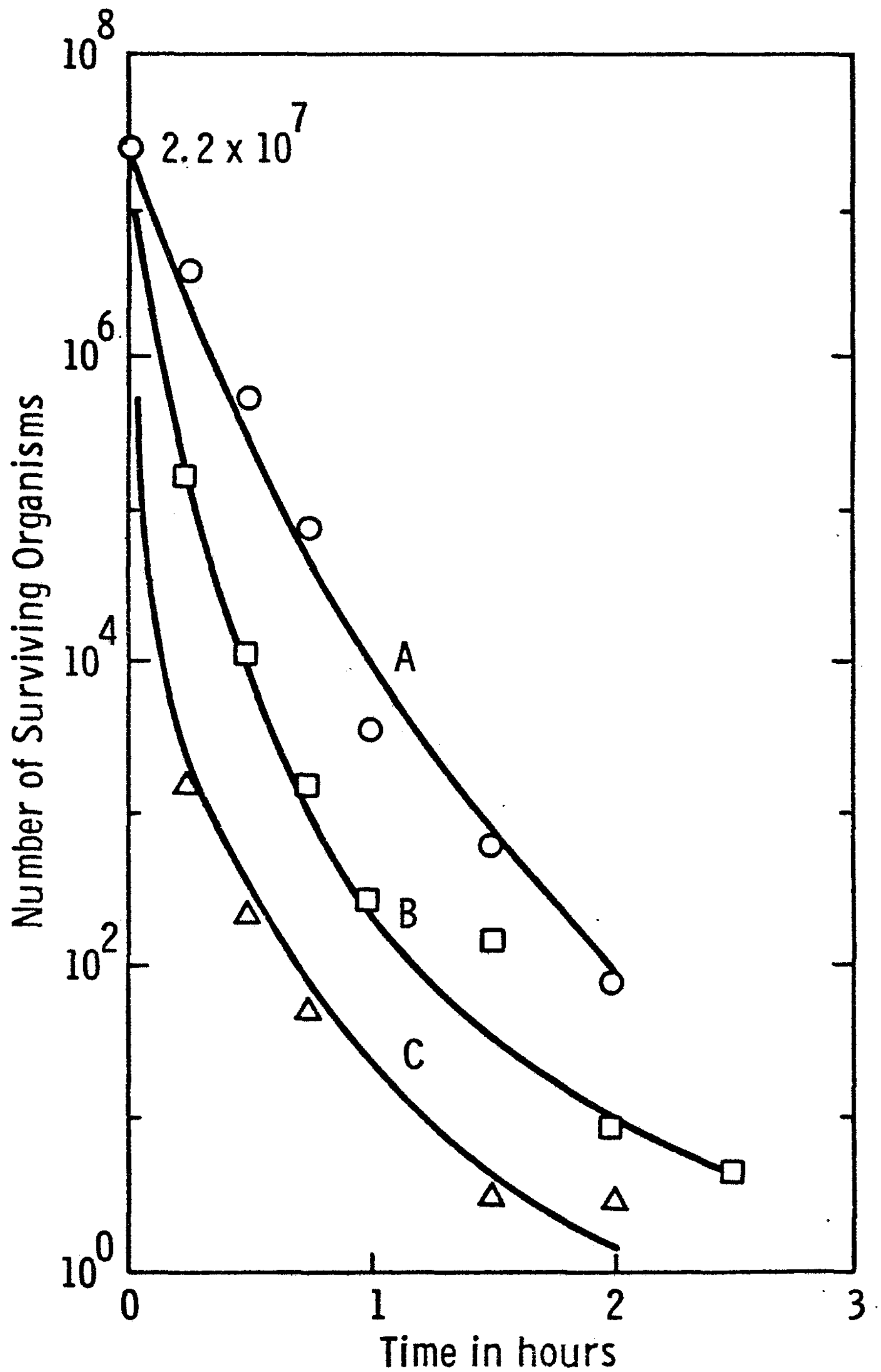
B. <u>Progress</u>. This quarter has been spent in further development of the model for thermal sterilization of microorganisms published in the above research report, SC-RR-67-256. In that report, the model was tested on thermal deactivation data which was convex (such as Silverman's data). Efforts this quarter have been directed toward testing the model using concave data.

By use of competing kill mechanisms it is possible to closely match the (concave) survival data for *Bacillus coagulans* given by Koesterer in *Studies for Sterilization of Space Probe Components*, contract NASw-550, Final Report, 1963. Their data for 125°C, 0, 135°C, □, and 145°C, Δ, with comparisons to expected survivors when the probability of survival, p(t), is given by

$$p(t) = [e^{-k_2 t}/(k_1+k_{-1})][k_1 e^{-(k_1+k_{-1})t} + k_{-1}]$$

$$\times \{1 - [1 - 1/(1+20k_3 t)]^{20}\}$$

are shown in Figure 1. The rationale which led to this equation was that sterilization of the microorganism may result from either the inactivation of a system consisting of several similar molecules by a first order reaction or the inactivation of a system consisting of an aggregate of molecules by a second order reaction (based on the types of reactions observed in the chemical debonding of DNA and the deactivation of protein aggregates found in the literature). Reaction rate constants for curve A of Figure 1 are $k_1 = 4$ hr.$^{-1}$, $k_{-1} = .003$ hr.$^{-1}$, $k_2 = 1$ hr.$^{-1}$, and $k_3 = 10$(molec. hr.)$^{-1}$. For curve B, the constants are $k_1 = 8$ hr.$^{-1}$, $k_{-1} =$



10^8
10^6
10^4
10^2
10^0
2.2×10^7
A
B
C
Number of Surviving Organisms
0
1
2
3
Time in hours

Figure 1

.025 hr^{-1}, k_2 = 2 $hr.^{-1}$, and k_3 = 40 $(molec.\ hr.)^{-1}$. The constants for curve C are obtained via the Arrhenius equation for a temperature of 145^{o}C under the assumption that curves A and B are for 125^{o}C and 135^{o}C, respectively. The constants are k_1 = 16 $hr.^{-1}$, k_{-1} = .18 $hr.^{-1}$, k_2 = 3.2 $hr.^{-1}$, and k_3 = 170 $(molec.\ hr.)^{-1}$.

The above was done by trial and error at the computer console, GE 235. In order to adapt the modeling for the generation of bioengineering parameters, an effort is under way to develop a computer program which would take survival data for three different temperature levels and identify the systems and rate constants subject to Arrhenius equation constraints. There is progress and it is hoped that this will be completed by the end of calendar 1967.

A paper, "A Rational Model for Thermal Sterilization of Microorganisms", based on the modeling of SC-RR-67-256 has been accepted for publication in Mathematical Biosciences. In addition, a paper, "A Logarithmic Extrapolation of Microbial Survivor Curves for Planetary Quarantine Requirements" was accepted for publication in Space Life Sciences.

6. Prediction of Microbial Burden.

A. Description. One of the significant factors associated with the variables occurring in microbial death prediction objectives is the microbial burden of the item being sterilized. As a first step toward predicting this burden in the case of space vehicles, a model was developed ("An Assembly Contamination Model", E. J. Sherry and C. A. Trauth, Jr., Sandia Laboratories Research Report

SC-RR-66-421) in which the parameters were random variables. Means for correlating these parameters with obtainable data are needed.

B. Progress. A model has been developed based upon the "plateau effect" observed in microbial deposition in a clean room. This model is expected to be valid "locally", that is, on small surfaces during relatively short time periods. Work has just begun on the extension of this model to treat complex surfaces of space vehicles for long periods of time. Should the result prove to be experimentally "verifiable", this model will become the nucleus of the implementation system described below.

7. Implementation System

A. Description. The objective of this activity is to design a system based upon modeling and experimentation to provide, at least, the following:

(i) statistical estimates of space vehicle microbial burdens, in toto, by part, component, subassembly, in interior, exterior and occluded categories, as a function of time,

(ii) statistical estimates (projections) of total space vehicle bioburden at any time, based on the estimate at that time, and

(iii) theoretical tolerable limits as a function of time for all categories listed above.

B. Progress. The result of this activity may be viewed as an information system. It is necessary to specify the inputs, the nature of the processor and the outputs. In these terms, the processor represents a computer code based upon much of the modeling referred to above. As already noted, progress has been made in this area during the last quarter. Some progress has been made in identifying the desired inputs, but the exact nature of the inputs will remain uncertain until the models are experimentally verified, and until the desired outputs are fully agreed upon.

Based upon the assumption that the modeling is, in fact, approximately what is needed, estimates have been made of the amount of computing time needed on a given flight program as a function of (among other things):

(i) the complexity of the program,

(ii) the speed of the computer, and,

(iii) the amount of microbial burden data to be taken.

A systems design study has been initiated to determine possible system configurations, and relationships with flight program systems, and with planetary quarantine organizations.

8. <u>Retrieval of Terrestrial Microorganisms from the Lunar Surface</u>

A. <u>Description</u>. This activity has as its goal the determination of the probability that a lunar lander experiment retrieves at least one viable terrestrial microorganism that has been deposited on the moon by previously impacting spacecraft. This goal is to be attained by estimating the contribution of each spacecraft impacting the moon to the distributed microbial burden on the lunar surface.

B. <u>Progress</u>. The first draft of a final report describing the work on this problem is being prepared. It was pointed out in the previous quarterly report that there were four sub-problems of concern, namely:

(i) The problem of the die-away of the at-launch microbial burden of a spacecraft during the flight from the earth to the moon.

(ii) The problem of the dispersal of surviving microorganisms upon impact of the spacecraft on the moon.

(iii) The problem of the attenuation of the dispersed microorganisms as a function of their residence time on the lunar surface.

(iv) The problem of the possibility of transport of microorganisms away from their initial points of deposition after impact dispersal.

As was stated in the previous progress report, sub-problems (i), (iii) and (iv) have, in principle, been resolved although no calculations for (i) and (iii) have yet been made.

In regards to sub-problem (ii), it is clear that there are only three ways in which microorganisms residing on or within a spacecraft can be scattered at impact: (a) Direct ejection at impact under the action of impulsive loadings of the surfaces on which microorganisms reside. (b) The ejection of spacecraft fragments to which microorganisms are attached. (c) The ejection of crater material (lunar soil) to which microorganisms may become attached at impact.

Each of these three means of dispersal has been examined in a qualitative fashion. A simple argument can show that direct ejection of microorganisms upon impact contributes a negligible amount of dispersal. A quantitative description of the ejection of spacecraft fragments upon impact has been developed using the analogy between break up during high-speed impact and explosive fragmentation. The results of calculations based on this analogy are likely to be conservative (in the sense that a greater dispersal of fragments is predicted than is observed). A quantitative theory of the ejection of crater material for impacts in loosely consolidated soils is not available (though some useable information exists for impacts on basalt). However, an appreciable amount of attachment of microorganisms to cratering material seems unlikely since the density of viable exposed organisms on the surface of the vehicle is small and the time available for attachment is short - roughly, less than a millisecond for impact speeds of 2.4 km/sec or more.

Thus, the ejection of fragments of the spacecraft is potentially the most significant means of scattering viable microorganisms over the lunar surface. To apply the theory of fragment dispersal to the several lunar probe impacts, some estimate is needed of the fraction of impact energy that goes into kinetic energy of the fragments. The work in progress at this time is devoted to this problem and to the consolidation of the remainder of the study.

9. Experimentation in Laminar Flow Environments

A. Description. A large problem in planetary quarantine is the correlation of measurements that can be made with actual spacecraft loading. The objective of this experimentation is to provide reliable data on which modeling of this problem can be based.

B. Progress. In order to obtain such data, experiments are being conducted in a specially designed vertical laminar flow device. Three experiments were completed during this period using intramural microorganisms to study deposition patterns and rates, and surface retention characteristics. A very limited amount of information was obtained about deposition patterns due to low concentrations collected. Higher concentrations of test contamination will be used in subsequent experiments. Data from these experiments did show extremely low surface collection for the amount of intramural contamination present in the air flowing past the models.

10. Surface Sampling Research and Development

A. Description. A device known as the vacuum probe has been developed in an effort to evaluate lightly loaded large surface areas for bacterial contamination. This device is described in detail in Reports SC-RR-67-114 and SC-RR-67-688.

B. Progress. Vacuum probes have been loaned to JPL and the Phoenix USPHS Field Station. Time was spent at Sandia with personnel from both locations on operation of the probe. Assistance to both organizations is continuing for experiments with the probe.

It has become necessary to redesign the probe-filter assembly portion of the probe since the supplier has discontinued his line of the two inch filter holder base. The new design has been completed and pilot models are being constructed. Drawings will be forwarded to all interested persons to replace probe details contained in SC-RR-67-688. The new holder design should provide a simpler and more positive air seal, and utilize a greater area of the filter for bacteria capture.

Experiments are being conducted to determine assay losses that have been experienced with removal of B. subtilis var. niger spores from surfaces with the probe. Experiments have shown a tendency toward very good assay efficiencies > 90%, with low concentration of microorganisms, decreasing to approximately 60% efficiency for very high concentrations. Several possible explanations have been offered for these losses; however, experimentation has not been completed to explain these losses.

A series of experiments were conducted to show the tendency of bare _B. subtilis_ var. _niger_ spores to adhere to clean smooth surfaces under different air flow velocities. The spores were aerosolized from a (95%) ethanol suspension and allowed to collect _dry_ on the surfaces of 4" x 7" aluminum strips. Some of these strips were subjected to air flow velocities of 100 ft/minute in a laminar flow room, and other strips were subjected to high pressure air streams varying up to 100 psi from a standard air "blow off" nozzle, spaced from 2" to 8" from the strips.

The extreme condition or most likely condition for spore blow off was considered to be the 100 psi air stream with the nozzle spaced two inches from the strips. _In all cases no significant spore "blow off" occurred_. This experiment emphasized the capability of the vacuum probe to remove small particles from surfaces since it has consistently removed _B. subtilis_ spores at better than 90% efficiency under similar conditions.

11. High Sample Rate Particle Counter

A. _Description_. Several pressing needs have prompted developmental work on a practical high rate particle counter. For a Class 100 clean room no adequate means now exists to obtain reliable test data in a reasonable length of time. This facet of clean room design is discussed in "Monitoring a Class 100 Clean Room" (SC-R-66-956).

Another important need for the sampler is to have a high enough sample rate to connect in series with the vacuum probe, as was described in "Development of an Increased Sampling Rate Monitoring System (SC-RR-66-585). According to "Principles of Operation of the Vacuum Probe Microbiological Sampler" (SC-RR-67-688), 1.5 cfm is needed as compared with the .01 to .1 cfm that is available from present samplers. By connecting the counter in series with the vacuum probe the microbiological and inert particles on a surface can be assayed directly.

B. Progress. Design for the subsystems of the optical system, theoretical calculations, and practical optical bench assemblies are being made. Two problems with the particle size resolution of this system are being examined. One problem is the uniformity of intensity of the light source for the particle counter, and the other is the energy loss from off-axis distortions in the scattered-light collecting subassembly.

12. Principles of Contamination Control

A. Description. The objective of this activity was to prepare a document, suitable for management use, describing the need for, and problems arising in, contamination control. The document is to be published by the Office of Technology Utilization, NASA.

B. Progress. All Sandia work on this project, except for review and approval of galley proofs, has been completed. Publication by the Government Printing Office is estimated by NASA to be about November 1, 1967.

13. Contamination Control Study

A. Description. The purpose of this project is to prepare a Contamination Control Handbook which can be used as a working document for people such as contamination control, design, manufacturing and quality control engineers.

B. Progress. Significant progress in developing and preparing this handbook was made during the quarter as evidenced by the following items of activity:

1. Approximately 120 pages of handbook material were prepared in rough draft form. This brings the total to about 150 pages and includes technical information, tables, charts and sketches on the following subjects:

   Contamination Control in Product Design

   Corrosion

   Soils

   Barrel, Abrasive Blast & Mechanical Cleaning

   Washing

   Drying

   High Purity Water

   Vapor Degreasing

   Atmospheric Air Contaminants

   Sources and Types of Atmospheric Contaminants

   Source Control of Atmospheric Contaminants

   Non-Laminar Air Flow Facilities

     Principle, Construction, Garments, Hoods

Laminar Flow Facilities

Vertical Flow Rooms, Curtain Units & Benches

Horizontal Flow Rooms, Tunnels & Benches

Packaging Films

Clean Packaging Films

Verification of Packaging Film Cleanliness

While some of this material is fairly well developed, most of it is in a preliminary draft form and will require revisions and additions.

2. A substantial amount of effort was devoted to preparing material on the following topics, although they are not yet completed to preliminary draft form:

   Ultrasonic Cleaning

   Charcoal Gas Filtration

   Microbial Filtration

   Gaseous Disinfectants

3. A discussion was held between Mr. F. J. Beyerle, Marshall Space Flight Center (MSFC), and Messrs. Sivinski, Whitfield, Garst and Lindell, 2570, regarding the status of the handbook project.

4. Visitors to Division 2572 were Mr. P. W. Morrison, WE, Allentown, and Mr. Anello P. Ross, Fairchild-Hiller Corporation, Germantown, Maryland. In both cases, information was obtained which may be used in the handbook.

5. Visits to companies engaged in contamination control activities in the Los Angeles and San Francisco areas resulted in the acquisition of high quality data for the Contamination Control Handbook. Places visited were tne (1) Los Angeles Air Pollution Control District,

(2) Turco Products, (3) Farr Company, (4) Richmond Corporation, and (5) Hamilton Manufacturing Company. Information and data obtained concerned the subjects of clean packaging materials, ultrasonic cleaning and cleaners, atmospheric pollutants, air filtration devices, clean benches, and non-laminar flow vented hoods.

6. Preparations were initiated for the MSFC Project Oral Review to be held in Denver, Colorado, October 25,26, 1967.

14. AEC-NASA Symposium

Improved contamination control through automation and instrumentation was the theme of a jointly sponsored AEC-NASA invitational symposium hosted by Sandia Laboratory at Albuquerque, New Mexico, September 12-14.

The three-day conference was organized into six sessions, each devoted to a specific contamination area of interest: contamination in liquids, air, and gases; surface and microbial contamination; and a systems approach to contamination control.

One-hundred thirty-five scientists and engineers representing contractors and government agencies involved in atomic energy and space programs heard 27 papers that either defined the present capabilities and limitations of contamination control monitoring equipment or examined the future needs for improved instrumentation. Panel discussions capped off three of the six sessions.

Most papers and speakers indicated that the need for better contamination control in the fields of atomic energy and space has outpaced the development of instrumentation, despite significant progress in recent years. One of the major problems noted was the lag between the definition of needed instrumentation and industry's response in supplying the instruments.

APPENDIX

Publications: Accepted

1. Brannen, J. P., "A Rational Model for Thermal Sterilization of Microorganisms", accepted for publication in Mathematical Biosciences.
2. Brannen, J. P., "On Logarithmic Extrapolation of Microbial Survivor Curves for Planetary Quarantine", accepted for publication in Space Life Sciences.
3. Brannen, J. P., "An Analysis for Sterilization Requirements", to appear in the Proceedings of the Rocky Mountain Symposium for Aerospace Science and Technology, sponsored by the American Astronautical Society, held in Denver.
4. Trauth, C. A., Jr., "A Systems Approach to Contamination Control", to appear in the Proceedings of the NASA-AEC sponsored Symposium on Current and Advanced Concepts in Instrumentation and Automation in Contamination Control, held in Albuquerque.
5. Dugan, V. L., "Principles of Operation of the Vacuum Probe Microbiological Sampler", Sandia Corporation Research Report, SC-RR-67-688, August 1967.
6. Dugan, V. L., "Automatic, Instantaneous Monitor for Counting the Bacterial Loading of an Aerosol", Sandia Corporation Technical Memorandum, SC-TM-67-687, August 1967.

Presentations:

1. Brannen, J. P., "An Analysis for Sterilization Requirements", Rocky Mountain Symposium for Aerospace Science and Technology, sponsored by the American Astronautical Society, held in Denver.

2. Trauth, C. A., Jr. (jointly with H. D. Sivinski, W. J. Whitfield and J. J. McDade), "Techniques for the Limitation of Biological Loading of Spacecraft Before Sterilization", Symposium on Sterilization Techniques for Instruments and Materials as Applied to Space Research, sponsored by the Committee on Space Research, International Council of Scientific Unions, London.

3. Trauth, C. A., Jr., "A Systems Approach to Contamination Control", Symposium on Current and Advanced Concepts and Instrumentation and Automation in Contamination Control, sponsored jointly by NASA and the AEC, held in Albuquerque.

4. Whitfield, W. J., "Present-day Laminar Flow Techniques", presented at a professional program on Clean Room Techniques which was presented by the Plant Engineering Department of Sandia Corporation, on July 13, 1967.

5. Morris, M. E., "Principles of Operation of the Vacuum Probe Sampler", Symposium on Current and Advanced Concepts and Instrumentation and Automation in Contamination Control, sponsored jointly by NASA and the AEC, held in Albuquerque.

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